

Reliability of Self-Regulated Repeated Sprint Performance in Male Professional Football Players

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The aim of the present study was to investigate reliability of self-regulated recovery time and performance during repeated sprints. For 4 trials, 6 professional male football players (18.8 ± 0.5 years, 182.4 ± 5.0 cm, and 77.4 ± 6.0 kg) completed 12 x 30 m (15 + 15 m) shuttle sprints, instructed to self-regulate (SR) recovery time to maintain performance. There were no between-trial differences in sprint time (ST), recovery time or fatigue index. ST showed a high degree of reliability for all trials (coefficient of variation [CV] ≤ 1.2 , intraclass correlation coefficient [ICC] ≥ 0.89). Recovery time became less variable and more consistent after trials 1-2 (CV = 11.9, ICC = 0.81) compared to trials 2-3 (CV = 7.7, ICC = 0.93), and trials 3-4 (CV

= 8.2, ICC = 0.92). There were no between-trial differences, but an effect of sprint number ($p < 0.05$) on physiological and perceptual measures, except that physical ratings of perceived exertion (P-RPE) had a significant reduction between trial 1 and 3 ($p < 0.05$). No sign of pacing during sprints when compared to criterion sprint ($p < 0.05$). Experienced subjects did not use less time to familiarize themselves compared to previous research, but after 2 trials they could maintain repeated sprint performance with a relatively short and consistent SR recovery time, without pacing their sprints. Self-regulated recovery could be used as a reliable and specific training method to maintain quality of sprint training sessions.

Introduction

In football, high-speed activities are repeatedly performed and account for ~ 9% of the total distance covered during a match (8, 33). However, repeated sprint ability (RSA), defined as the ability to perform repeated sprints with short recovery periods, is viewed as an important component of football (35).

Tests of RSA typically consists of short durations (<6 s) and passive recovery periods (<60 s) (35), with the determinants of performance being the ability to produce a high sprint speed, and resist fatigue in order to maintain these high sprint speeds for subsequent sprints (24). In repeated sprint exercise, typical work-rest ratios employed are 1:4, 1:6 and 1:10 (1, 30). These work-rest ratios have led to a performance decrement in subsequent sprints for distances between 30-50 m (1). Since recovery between repeated sprints is predominantly aerobic, primarily involving the resynthesis of phosphocreatine (PCr) and removal of inorganic phosphate (21), those with a greater aerobic capacity should be better able to maintain performance (17). Thus, the use of set work-rest periods may not be appropriate, as individual differences in factors such as aerobic capacity may lead to different training stimuli, and hence different training responses, between individuals (26). Therefore, it may be more appropriate for individuals to regulate their own recovery time between repeated sprint work.

Recent studies have demonstrated that following two familiarization trials, individuals are able to reliably self-regulate (SR) recovery time in order to maintain running (24) and cycling (34) repeated sprint performance. These studies used recreationally trained subjects with limited experience of repeated sprint exercise. There is evidence that greater experience of an exercise can improve the ability to pace and regulate (25, 32), and that this is associated with a higher standard of performance (29). Therefore, using individuals with greater experience of repeated sprinting, and who are known to self-pace during match play (19), may show greater reliability in performance, as greater experience can lead to a greater tolerance of discomfort without experiencing premature fatigue (32).

Furthermore, different exercise modes are reported to induce different physiological, mechanical and perceptual responses which affects pacing strategies (3, 14, 18), and only moderate correlations are found between cycling and over ground running repeated sprint performance (35). Thus, as environmental differences influence pacing, it is important to investigate SR of repeated sprinting in an environment specific to the population used.

The aim of this study was to investigate the reliability of SR repeated sprint performance in male professional football players. Due to subjects' greater experience in repeated sprinting, it was hypothesized that less familiarization was needed to achieve a stable SR repeated sprint performance level compared to previous research (24, 34).

Methods

Experimental Approach to the Problem

Subjects completed four trials consisting of 12 x 30 m (15 + 15 m) shuttle sprints, to account for learning effects and ensure sufficient data for familiarization and reliability analysis (24, 34). Each shuttle sprint was performed with one change of direction (COD) of 180°. Additionally, prior to the repeated sprint protocol in trial 1, subjects' criterion sprint was assessed for investigation of self-pacing strategies during the repeated sprint protocol. Subjects SR recovery time with the goal to maintain sprint performance for all sprints. All testing was conducted on an indoor artificial surface (Astroturf) wearing football boots. Main outcome measures assessed were sprint time (ST), SR recovery time, and fatigue index (FI). Indication of physiological and psychological strain was provided by heart rate monitoring (HR), physical ratings of perceived exertion (P-RPE) (7) and task effort awareness (TEA) (37).

Within subjects, all trials were conducted at approximately the same time of day, with a minimum of 3 days and a maximum of 4 days between trials in order to provide adequate recovery and avoid fatigue effects. Potential influence of within subject differences in energy intake on performance (28) was accounted for through instructing subjects to complete a 24hr food diary prior to 1st trial, and to replicate this dietary intake before subsequent trials. Additionally, subjects were asked to avoid caffeine consumption and strenuous exercise for 24hrs before testing. Subjects were allowed to consume water ad libitum during trials. Adherence to these instructions was verbally confirmed before initiating each trial (34).

Subjects

Six professional young male soccer players (18.8 ± 0.5 years, 182.4 ± 5.0 cm, and 77.4 ± 6.0 kg), participated in the study. All subjects had good

experience in repeated sprint protocols. Prior to initiation of trials, subjects was informed on the procedures of testing and familiarized with the use of P-RPE and TEA, based on the instructions by Swart et al. (37). Following this, subjects completed a medical questionnaire and signed informed consent form. The study received approval from the Ethics Sub-Committee for the MSc in Strength & Conditioning at the University of Edinburgh.

Procedures

Height (cm) and body mass (kg) were recorded using a combined height stadiometer and digital scale (SECA 769 Digital Medical Scale, Hamburg, Germany), while wearing shorts only. Before initiation of each trial subjects completed a standardised warm up consisting of 10 x 20 m jog (self-paced), 3 x 10 high knees, heel flicks and walking lunges. This was followed by 3 x 6 dynamic stretches of each leg, targeting hamstrings/lower back, gluteus and quadriceps. They concluded the warm up with 3 practice sprints of increasing intensity, instructed as 70 %, 80% and 90% of self-determined maximum sprint speed, respectively, and 5 minutes of passive rest. Sprint time was measured using a photocell system (Brower Test Centre System, SL Utah, USA). Self-regulated recovery time was measured by a digital stop watch to the nearest 0.1 second (11). Sprints were all initiated 1 m behind the speed gates to avoid false triggering, and start technique was standardised by having one foot in front on the line, one foot backwards, and avoid “rolling” backwards when initiating sprint. Prior to each trial, subjects were informed on the number of sprints to be executed, 12 x 30 m shuttle sprints, to give a maximal effort for each sprint, and to provide themselves with sufficient recovery time in order to replicate performance from the criterion sprint for all of the 12 sprints (24, 34). Further, they were reminded of the use and meaning of the P-RPE and TEA scale, and the importance of meeting the 15 m end line with one foot before turning. Due to time constraint in such a high-performance environment, two subjects were tested at approximately the same time in the same facility but in different running lanes. To eliminate competition effect, subjects were informed before each trial that communication with the other subject was not allowed until completion of the trial. Between each sprint, subjects rested passively, defined as standing and walking in a restricted area close to the area of sprint initiation. Before each sprint and after the 180° COD, subjects were provided with verbal feedback to encourage maximal effort. Further, subjects were instructed to provide a 3 second countdown, which they should try to factor into their

recovery time, before initiating next sprint (34). Recovery time was defined as the immediate end of previous sprint until initiation of next sprint, immediately after the 3 second countdown (34). Subjects were given no feedback on performance, and no timepieces were available in the facility.

Trial 1. Before subjects initiated the repeated sprint protocol in the first trial, their criterion sprint performance was assessed. Subjects completed the standardised warm up, but with a 2 min passive rest between the last practice sprint and initiation of the criterion sprint assessment. Subjects were instructed to perform a single maximal 30 m shuttle sprint. Immediately after completion of the sprint, subjects completed a 1 min jog and 5 min of passive rest before conducting a second sprint (34). If sprint performance in the second sprint was slower than sprint one, the time in sprint one was taken as the criterion performance. If sprint time in sprint two was $\geq 5\%$ faster than sprint one, a third sprint was conducted. This process continued until sprint time no longer decreased (34). After criterion sprint performance was assessed, subjects rested passively for 5 min before initiating the repeated sprint protocol.

Trials 2-4. Trial 2-4 consisted only of the standardised warm up, mentioned previously, and the repeated sprint protocol.

Measurements. After completion of all four trials, maintenance of sprint performance was determined using the following criteria:

1. absence of any obvious pattern of fatigue, determined as continuous drop off in performance (24, 34):
2. a within-trial coefficient of variation (CV) for mean ST $\leq 1.79\%$ (the upper confidence limit of the CV of mean sprint time in 30m sprints) (22).

In addition to ST and SR recovery time, FI was calculated using the following equation: $\text{fatigue} = (100 \times (\text{total sprint time} / \text{ideal sprint time})) - 100$, where total sprint time = sum of sprint times from all sprints, and ideal sprint time = number of sprints \times fastest sprint time (23).

HR, with a high test-retest reliability (2), was collected in 1 second intervals throughout the protocol using the Polar Team 2 system (Polar Electro Oy, Kempele, Finland). Additionally, P-RPE and TEA were collected approximately 5 second after each sprint (34). These scales separately quantify physical sensation and mental effort, and have an important role in regulation of exercise intensity (37).

Statistical Analysis

Measures of centrality and spread are represented as mean \pm SD. Before conducting analysis data were assessed for normality using the Shapiro-Wilk test. A published spreadsheet (27) was used to calculate changes in the mean, intraclass correlation coefficient (ICC), standard error of measurement (SEM), and CV for ST, recovery time and FI in order to assess reliability between pairs of trials. A within-trial CV of ST and recovery time was calculated for each subject from the following equation: $((SD/mean) \times 100)$, to assess most reliable trial for sprint performance and recovery time. All other analysis were conducted using the Statistical Package for Social Sciences (SPSS for Windows, SPSS, Inc., Chicago, IL, USA). One-way repeated measures analysis of variance (ANOVA) compared mean ST, recovery time, FI, P-RPE, TEA and peak HR over the 4 trials. Further, one-way repeated measures ANOVA compared effect of sprint number from the most reliable sprint performance trial on ST, recovery time, P-RPE, TEA and peak HR. A paired sample t-test compared criterion sprint with mean ST from all trials and from the most reliable sprint performance trial. Additionally, a one way repeated measures ANOVA compared criterion sprint with fastest and slowest ST from the most reliable sprint performance trial. If assumption of sphericity was violated Greenhouse-Geisser adjustment was applied, and significant main effects were explored by planned comparisons using simple first contrasts. Pearson's correlations between P-RPE and TEA, and perceptual responses and sprint number were calculated for each subject for each trial. To calculate mean correlation for each trial a published spreadsheet was used (16). Significant mean differences between trials was quantified by Cohen's d effect sizes as small ($d \leq 0.2$), medium ($d > 0.2$ and $d < 0.8$), and large (≥ 0.8) (12). Significance level was set at $p \leq 0.05$.

Results

Mean results for each performance variable and perceptual responses are in Table 1. Performance variables and TEA did not differ across the four SR trials ($p > 0.05$), but there was a significant effect of trial for P-RPE ($p \leq 0.05$). Reliability analyses are in Table 2. For recovery time, the variation (SEM and CV) was reduced and measurements more consistent (ICC) after the first pair of trials. ST, for all pairs of trials, showed ICCs > 0.88 , and CVs $< 1.3\%$. FI demonstrated considerably less consistency, and greater variabil-

ity. Table 3 present the within-trial CV, demonstrating a maintenance of performance for each trial as ST, with trial two being the most reliable one. For recovery time there was progressively less variation for each trial.

Table 1. *Mean \pm SD main outcome variables across the four self-regulated recovery trials ($n = 6$)*

	Trial 1	Trial 2	Trial 3	Trial 4
Recovery time (s)	76.3 \pm 17.3	76.7 \pm 15.1	69.0 \pm 14.2	70.4 \pm 13.5
Sprint time (s)	5.57 \pm 0.14	5.55 \pm 0.16	5.64 \pm 0.15	5.62 \pm 0.19
Fatigue index (%)	1.7 \pm 0.3	1.7 \pm 0.4	2.5 \pm 0.9	2.3 \pm 0.6
P-RPE*	11.53 \pm 2.51	10.47 \pm 2.41	10.11 \pm 2.26	9.90 \pm 2.95
TEA	1.82 \pm 2.99	1.25 \pm 2.33	0.39 \pm 1.75	0.36 \pm 1.84

P-RPE = physical ratings of perceived exertion, TEA = task effort and awareness ratings.

*Significantly different when comparing trial 1 to 3.

Table 2. *Pairwise reliability of performance variables during self-regulated repeated sprint exercise ($n = 6$).*

	ΔMean	ICC	SEM	CV
Recovery time (s)				
Trial 1-2	0.43 (-13.29 to 14.15)	0.81 (0.15 to 0.97)	9.24 (5.77 to 22.67)	11.9 (7.2 to 31.6)
Trial 2-3	-7.76 (-14.63 to -0.88)	0.93 (0.60 to 0.99)	4.63 (2.89 to 11.37)	7.7 (4.8 to 20.0)
Trial 3-4	1.43 (-6.10 to 8.96)	0.92 (0.55 to 0.99)	5.07 (3.17 to 12.44)	8.2 (5.1 to 21.4)
Sprint time (s)				
Trial 1-2	-0.01 (-0.11 to 0.08)	0.91 (0.50 to 0.99)	0.06 (0.04 to 0.15)	1.1 (0.7 to 2.8)
Trial 2-3	0.08 (-0.02 to 0.19)	0.89 (0.43 to 0.98)	0.07 (0.04 to 0.17)	1.2 (0.8 to 3.1)
Trial 3-4	-0.02 (-0.11 to 0.07)	0.94 (0.65 to 0.99)	0.06 (0.04 to 0.15)	1.1 (0.7 to 2.7)
Fatigue index (%)				
Trial 1-2	0.03 (-0.25 to 0.31)	0.88 (0.39 to 0.98)	0.19 (0.12 to 0.46)	11.4 (7.0 to 30.4)
Trial 2-3	0.72 (-0.44 to 1.88)	-0.32 (-0.86 to 0.57)	0.78 (0.49 to 1.92)	41.6 (24.2 to 134.6)
Trial 3-4	-0.13 (-0.70 to 0.45)	0.86 (0.29 to 0.98)	0.39 (0.24 to 0.95)	16.4 (9.9 to 45.0)

Values in parentheses are 95% confidence limits. ICC = intraclass correlation coefficient; SEM = standard error of measurement; CV = coefficient of variation.

Table 3. Mean \pm SD and range of within trial CV for RT and ST ($n = 6$).

	Trial 1	Trial 2	Trial 3	Trial 4
Recovery time	19.7 \pm 4.4 (13.1-24.7)	12.0 \pm 4.6 (5.4-18.7)	14.9 \pm 7.2 (6.9-27.2)	11.8 \pm 5.7 (8.5-23.1)
Sprint time	1.21 \pm 0.48 (0.81-2.15)	1.03 \pm 0.25 (0.74-1.45)	1.43 \pm 0.53 (0.78-2.26)	1.34 \pm 0.43 (0.98-1.55)

Values in parenthesis are range.

Pattern of recovery time and ST from the most reliable sprint performance trial are presented in Figure 1 and 2, respectively. There was no significant effect for trial (recovery time: $F_{[3,15]} = 1.783$, $p > 0.05$, and ST: $F_{[3,15]} = 2.837$, $p > 0.05$), or sprint number (recovery time: $F_{[2,30, 11.50]} = 1.462$, $p > 0.05$, and ST: $F_{[3,44, 17.19]} = 0.493$, $p > 0.05$). For FI, there was no significant effect for trial ($F_{[1,13, 5.66]} = 3.709$, $p > 0.05$).

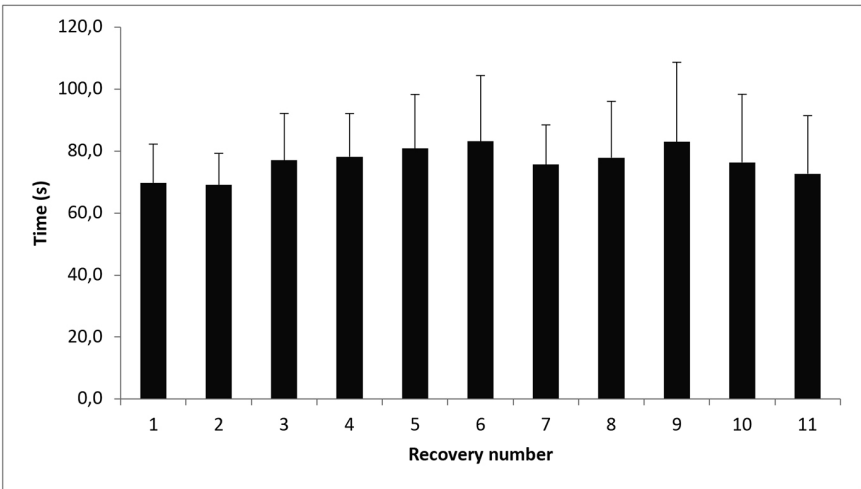


Figure 1. Mean self-regulated recovery time across the repeated sprint exercise from the most reliable sprint performance trial (trial 2) ($n = 6$).

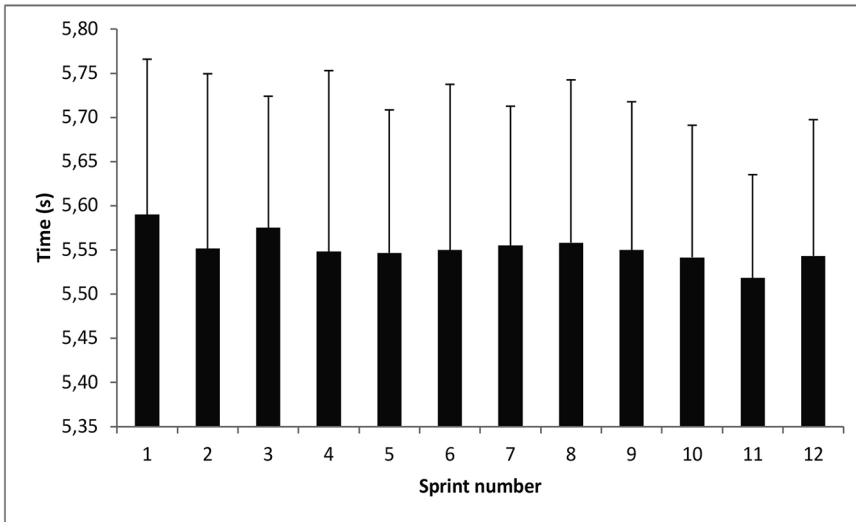


Figure 2. Mean sprint time across the repeated sprint exercise, from the most reliable sprint performance trial (trial 2), with self-regulated recovery time ($n = 6$).

Results for criterion sprint compared to mean ST trial two and mean ST for all trials are in Figure 3, while Figure 4 represents comparisons between criterion sprint, fastest and slowest ST from trial two. There was no statistical difference between criterion sprint and mean ST from trial two ($t(5) = 0.609$, $p > 0.05$), or mean ST from all trials ($t(5) = -0.161$, $p > 0.05$). Also, there was no statistical difference between criterion sprint, fastest and slowest ST from trial 2 ($F_{[2,10]} = 0.592$, $p > 0.05$).

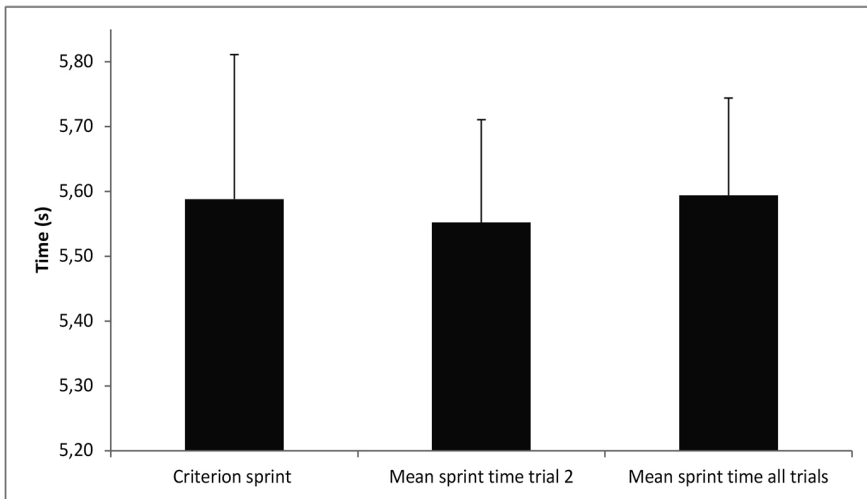


Figure 3. *Criterion sprint compared to mean sprint time from most reliable sprint performance trial (trial 2) and overall mean sprint time (n = 6).*

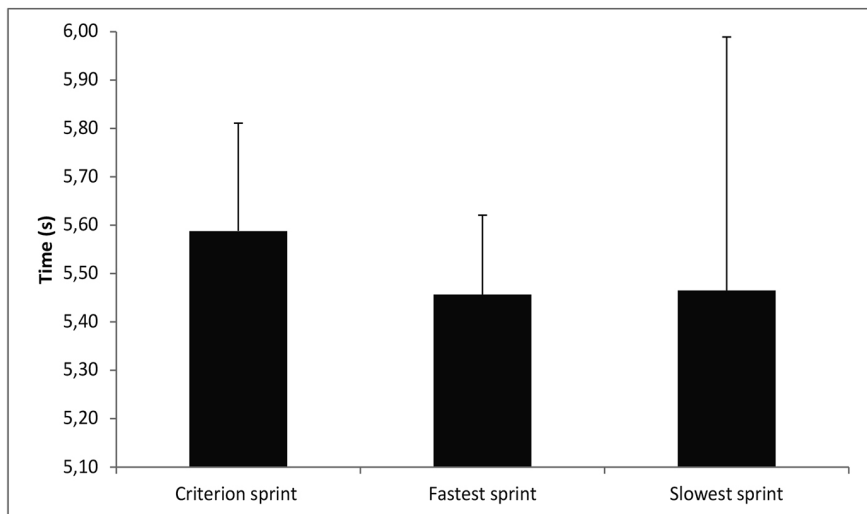


Figure 4. *Criterion sprint compared to the fastest sprint time and slowest sprint time in the most reliable sprint performance trial (trial 2) (n = 6).*

Pattern of P-RPE and TEA from most reliable sprint performance trial are in Figure 5 and 6. There was a significant effect of trial for P-RPE ($F_{[3,15]} = 4.053, p < 0.05$) with a decreased perceptual responses when comparing trial 1 and 3 ($p < 0.05, d = 1.93$), but not for TEA ($F_{[1,393, 6,966]} = 2.042, p > 0.05$).

However, there was a significant effect of time for both measures (P-RPE: $F_{[1.730,8.652]} = 47.779$, $p < 0.05$, and TEA: $F_{[1.826,9.130]} = 19.644$, $p < 0.05$), where simple contrasts demonstrated P-RPE to be significantly greater in sprint 3-12 compared to sprint 1 ($p < 0.05$, $d = -2.89$, $d = -2.76$, $d = -2.76$, $d = -4.43$, $d = -4.16$, $d = -4.16$, $d = -5.30$, $d = -4.72$, $d = -5.04$, $d = -4.54$, respectively), and TEA to be significantly greater in sprint 3-12 compared to sprint 1 ($p < 0.05$, $d = -2.60$, $d = -1.91$, $d = -1.91$, $d = -2.63$, $d = -4.63$, $d = -8.68$, $d = -5.37$, $d = -4.71$, $d = -4.21$, $d = -3.21$, respectively).

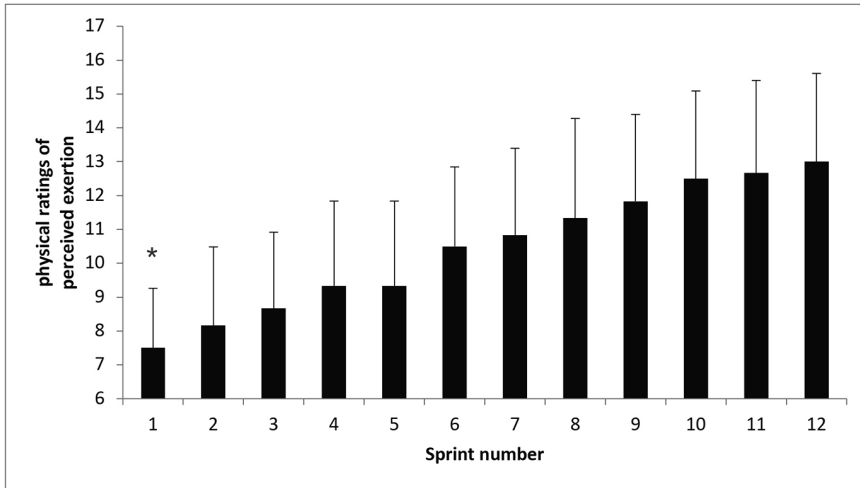


Figure 5. Physical ratings of perceived exertion after each sprint, from the most reliable sprint performance trial (trial 2), with self-regulated recovery time ($n = 6$). *Significantly different from sprint 3-12 ($p \leq 0.05$).

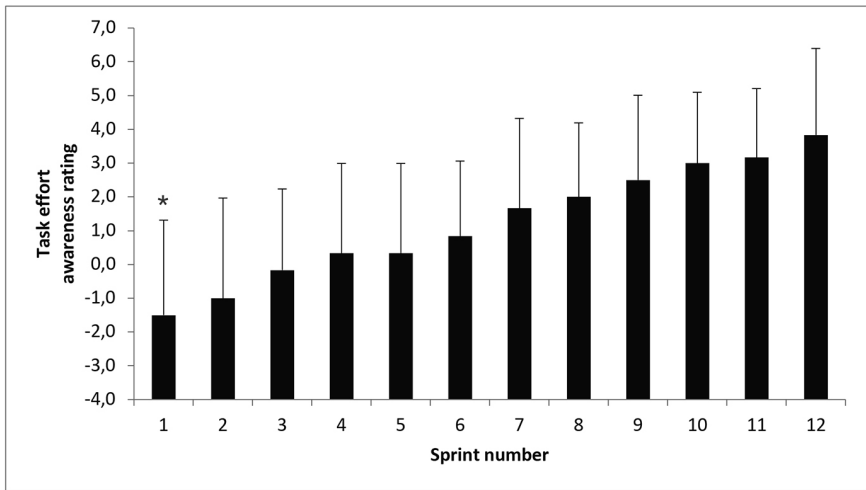


Figure 6. Task effort awareness ratings after each sprint, from the most reliable sprint performance trial (trial 2), with self-regulated recovery time ($n = 6$). *Significantly different from sprint 3-12 ($p \leq 0.05$).

Table 4 demonstrates strong positive correlation values between TEA and P-RPE, and these perceptual responses and sprint number, for all trials ($r^2 \geq 0.88$). HR was not significantly affected by trial ($F_{[3,12]} = 0.285$, $p > 0.05$) (Figure 7). However, there was a significant effect of time ($F_{[2,422,12,110]} = 8.712$, $p < 0.05$) (Figure 8), where simple contrasts demonstrated sprint 2-12 being significantly greater than sprint 1 ($p < 0.05$, $d = -4.01$, $d = -2.34$, $d = -2.59$, $d = -3.32$, $d = -2.70$, $d = -2.96$, $d = -3.44$, $d = -3.42$, $d = -2.43$, $d = -2.79$, $d = -2.53$, respectively).

Table 4. Mean correlation values between P-RPE and TEA, and sprint number and P-RPE and TEA ($n = 6$).

	Trial 1	Trial 2	Trial 3	Trial 4
SN and P-RPE	0.97 (0.82-0.99)	0.98 (0.94-0.99)	0.97 (0.95-0.99)	0.96 (0.87-0.98)
SN and TEA	0.90 (0.19-0.98)	0.94 (0.74-0.99)	0.96 (0.65-0.99)	0.96 (0.89-0.99)
P-RPE and TEA	0.88 (0.00-0.97)	0.94 (0.81-0.99)	0.90 (0.64-0.96)	0.95 (0.90-0.99)

Values in parenthesis are range. SN = sprint number, P-RPE = physical ratings of perceived exertion, TEA = task and effort awareness.

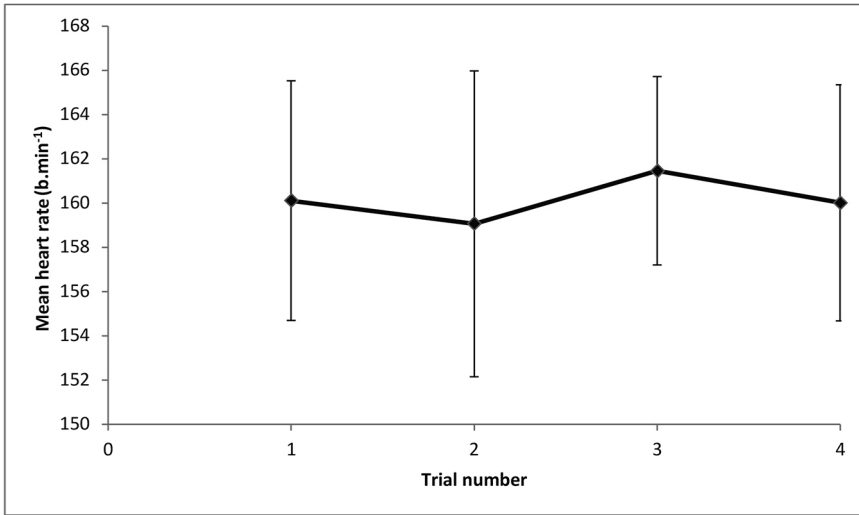


Figure 7. Peak heart rate response for the repeated sprint exercise in each trial ($n = 5$).

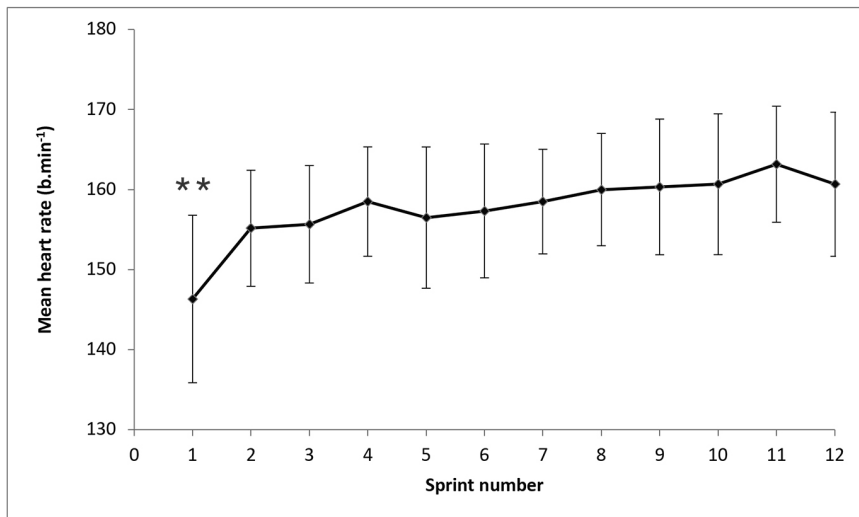


Figure 8. Peak heart rate response for each of the repeated sprints, from the most reliable sprint performance trial (trial 2), with self-regulated recovery time ($n = 6$). **Significantly different from remaining data ($p \leq 0.05$).

Discussion

The aim of this study was to investigate the reliability of SR repeated sprint performance in male professional football players. It was hypothesized that subjects with greater experience in repeated sprint exercise would need less familiarization than subjects in previous research (24, 34).

Reliability analysis of ST showed a high degree of consistency and little variation across all trials, as evidence of ICC and CV, respectively (Table 2). This is further supported by both the within trial CV (Table 3) and the non-significant between-trial differences, highlighting that subjects produced consistent ST from the very first trial. However, pairwise reliability results showed that SR recovery time became progressively more consistent and less variable after trials 1-2, which is quite similar to that of previous research (24, 34). Therefore, it seems like subjects with presumed greater experience in this type of exercise still needed the same amount of familiarization before repeated sprint performance was maintained with relatively stable recovery times. In fact, there was a greater reduction between trials 1-2 and 2-3 for CV in this study ($CV = 4.2$) as opposed to Glaister et al. (24) ($CV = 2.4$), indicating a greater degree of familiarization occurred for the more experienced subjects. These reliability results are a bit surprising, as greater experience should lead to improved pacing and regulation (25, 32). Testing in this study was conducted with two subjects at approximately the same time, but in different running lanes. Therefore, competition effect could have acted as a confounding variable, as presence of another athlete has shown to increase perceived performance (4). This could mean that recovery time, at least for the first trials, was affected for subjects, and could further explain the variation in chosen recovery time between individuals, seen as a high within trial CV and SD for each trial. The variation could also be explained by different fitness abilities. Subjects with a greater aerobic fitness would recover faster between sprints and better maintain performance (17, 21), and that subjects with faster sprint times may experience greater metabolic strain, and thus need longer recovery periods (24). The present reliability results additionally confirms that there is no gold standard for the calculation of FI, and different measures shows great variability (23) (Table 2).

When comparing results across studies it is important to consider sprint duration and type of modality, with focus on the latter as this is the main difference between research in this area. Variation in sprint duration affects maintenance of repeated sprint performance (1), and this could affect ability

to SR performance. Next, decrement scores are reported to be generally greater for intermittent cycling than for running (6), which is supported by the greater FI and recovery times for the repeated sprint cycling protocol (34) as opposed to results when using running as the modality in this study and in Glaister et al. (24). Additionally, sprints with a COD are reported to induce greater metabolic stress, higher blood lactate concentrations and a higher pulmonary oxygen uptake, compared to linear sprinting (10). However, since greater running speed is related to greater fatigue development during multiple sprint work (31), speed decrements are reported to be lower for intermittent sprints with a COD compared to intermittent linear sprinting (10, 13). This is unclear when comparing FI results in this study with those in Glaister et al. (24), where FI for the latter were higher in the first 2 trials, with no notable difference in the last 2 trials. It might have been some interference from football specific training sessions conducted on days prior to testing which affected these results.

Even though there was a relatively small amount of fatigue and a stable performance during the repeated sprint protocol, P-RPE, TEA and HR progressively increased over time in the present study, which is in accordance with the previous research (24, 34). The coherent increase in P-RPE and TEA can be supported by the strong positive relationship seen between them in this study, supporting the findings that they are distinct but related cues (37). Glaister et al. (24) argued that the progressive increase in RPE, meant that the subjects only gave themselves sufficient recovery time in order to maintain performance. However, Phillips et al. (34) assessed accuracy of recovery time by reducing it by 10 % from the most reliable SR recovery time, and found that performance was still maintained with no impairment of the psychophysiological ratings; HR, P-RPE or TEA. They concluded that subjects overestimated recovery time needed. Since full recovery is not required for maintenance of repeated sprint performance (20), or improvements in sprint performance (15), this could lead to a lack of sufficient stimulus if the intensity is not appropriate. In order to provide more accurate recommendations, further research should address this issue since it might not be the same for repeated sprint running.

As ST lasted between 5-6 s, the primary fuel sources for a single maximal sprint would be ~ 50% PCr and ~ 40% anaerobic glycolysis, with an increasing aerobic contribution as the sprints progress (21, 35). On the other hand, as PCr resynthesis reach half-time after ~ 27 s (38), chosen recovery time for subjects in the present study would likely have led to continuous reliance of PCr as the primary fuel source. In addition, it is less likely that

anaerobic glycolysis would have been a limiting factor due to the short duration of the repeated sprint protocol, but that increased acidosis could impair ATP resynthesis rate (21). The increased intramuscular acidosis may explain the progressive increase in P-RPE, TEA and HR (24), which may further be supported by an additionally increased aerobic contribution, increasing cardiorespiratory demand and afferent feedback (34). This may also explain the individual variations in the relationship between sprint number and the perceived physical and psychological ratings as different fitness qualities in football are position specific, with significant differences in aerobic fitness levels between positions (36), leading to variation in perceptual responses to the sprints. Further, these relationships were stronger, and with less variation, than those in Phillips et al. (34), suggesting that subjects in this study were a more homogenous group and that type of exercise mode induce different perceptual responses (14).

Physical ratings of perceived exertion were significantly reduced between trial 1 and 3, with a pattern of decline across all trials. As experience and knowledge about the work to be done affect pacing strategies (5, 32), the familiarization may have led subjects to finding the activity progressively easier. However, in contrast to Phillips et al. (34), this study found no statistical difference between criterion sprint compared to fastest, slowest and mean ST in trial 2, or mean ST overall, which suggest that occurrence of pacing strategies was unlikely for the repeated sprints. This is further supported by the moderate TEA values seen in this study, as a greater increase in the sense of effort could have led to a voluntary reduction in exercise intensity (37). Research is unclear about the minimum intensity required for adaptations in sprint performance, but a maximal effort seems to be recommended for each sprint (26). Even though no significant differences were found for ST between trials for this study, the chosen recovery times and the lack of pacing, may have lead to a maximal effort being achieved for each sprint, thus leading to enhancements in sprint performances.

To the author's knowledge this is the first study to investigate reliability of SR performance in male professional football players, and in a setting specific for this type of sport, which is important since different exercise modes lead to different physiological, mechanical and perceptual responses (3, 14, 18). Since COD ability has shown to be an important determinant in team sport performance (9), and that straight line sprinting does not improve COD performance (39), specificity must be considered when programming this type of work for football players. Probably, the greatest limitation of

this study was the small sample size, which could lead to a failure in detecting a true effect and lowering the external validity.

In conclusion, male professional football players seems to use the same amount of familiarization as subjects with less experience, and after two trials they can reliably maintain repeated sprint running performance with a relative short and consistent SR recovery time.

Practical applications

This is the first study to assess SR of recovery time in an elite population, where it seems to be a reliable method of maintaining repeated sprint performance and resist fatigue in sprints with a change of direction. Additionally, there was no evidence of pacing during the sprints, which is important as a maximal effort seems to be warranted to enhance sprint performance. Therefore, since set work-rest ratios assessed in the literature usually leads to a decreased performance for subsequent sprints, and players within a team may possess different physical abilities, coaches can use this as a tool to maintain quality of a training session, tailored to each individual's ability. In addition, as linear sprinting does not improve sprinting with a COD, these results provide specific implications for coaches. However, as improvements in sprint performance may not depend on full recovery between sprints, coaches should bear in mind that accuracy of SR recovery time was not assessed in this study.

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